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Gene Pyramiding in Plant Breeding: Advancements, Techniques, and Significance

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Gene pyramiding, a technique for stacking multiple desirable genes into a single genotype, has revolutionized the field of plant breeding. This strategy, facilitated by advancements in molecular genetics and associated technologies like Marker Assisted Selection (MAS), allows for the simultaneous expression of multiple genes in a single plant, leading to durable resistance against various stresses. The concept of gene pyramiding was first introduced by Watson and Singh in 1953. This revolutionary approach in plant breeding aimed to assemble multiple desirable genes from different parents into a single genotype. The ultimate goal of gene pyramiding is to create a genotype with all the target genes, which can be particularly useful in improving existing elite cultivars for traits that are unsatisfactory (Fig. 1).

Gene Pyramiding

Gene pyramiding in plant breeding can be achieved using both traditional and modern breeding programs. Traditional pyramiding methods involve backcross breeding, which includes crossing a hybrid with one of the parental lines and then selecting for the desired trait through a series of backcrosses, pedigree breeding, or recurrent selection. The inherited qualities and resistance genes are transferred from donor parents onto recipient lines.

The pyramiding process can be divided into two phases: the Pedigree phase and the Fixation phase. The Pedigree phase is designed to include all target genes in a single genotype, known as the root genotype. In the Fixation phase, the target genes are fixed in a homozygous state to obtain the optimum genotype.

Modern Techniques in Gene Pyramiding

Marker Assisted Selection (MAS) is a key molecular technique used in gene pyramiding. It enables the rapid and precise incorporation of desirable traits into new cultivars. By utilizing molecular markers or DNA tags associated with desirable traits, gene pyramiding becomes more efficient.

Marker Assisted Backcross Breeding (MABB): MABB is a straightforward form of marker-assisted selection that involves transferring one or more genes or Quantitative Trait Loci (QTLs) from a donor parent into a superior cultivar or genotype. This technique plays a crucial role in backcross breeding for pyramiding multiple genes related to stress tolerance.

Marker Assisted Recurrent Selection (MARS): MARS is an advanced method that allows for genotype selection and intercrossing within a single crop season. It streamlines the gene pyramiding process, making it more efficient and effective.

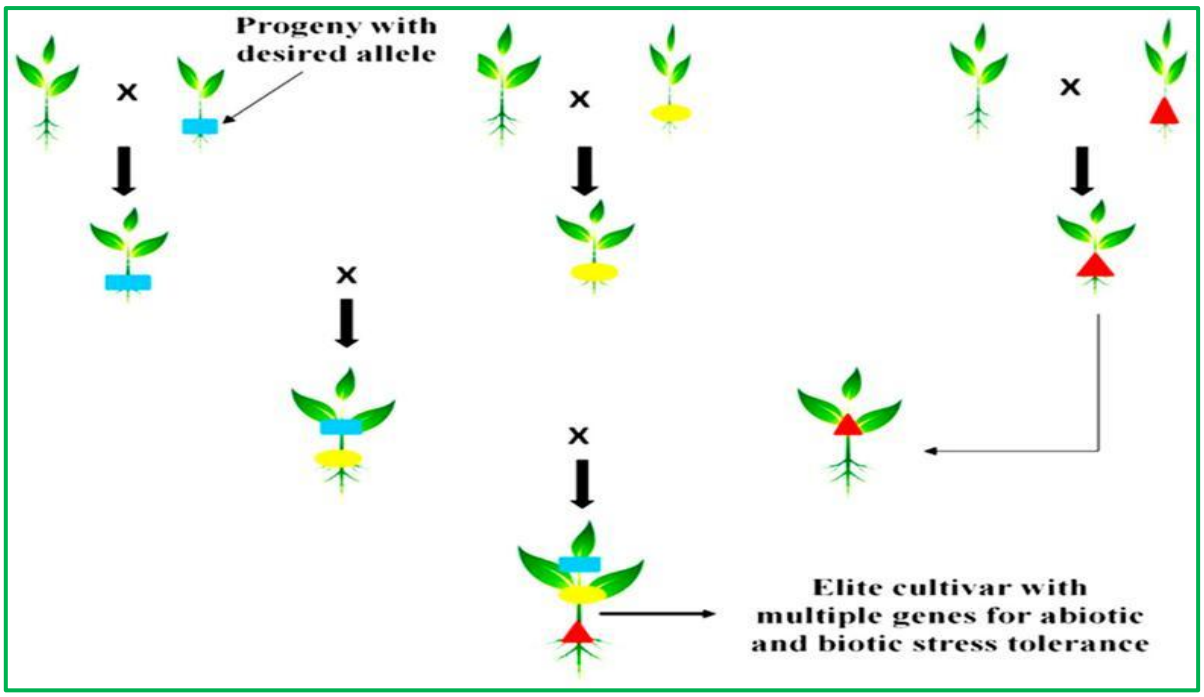

Fig: 1 - A pictorial view of gene pyramiding for sustainable crop improvement against biotic and abiotic stresses (Dormatey *et. al.*, 2020).

Significance of Gene Pyramiding in Agricultural Sustainability

Gene pyramiding has made significant contributions to modern agriculture by enhancing resistance to diseases, insect pests, and abiotic stresses, while also increasing crop yields. Molecular markers and MAS have enabled rapid and accurate plant breeding, allowing early generation selection for essential traits without the need for extensive field research.

One of the key benefits of gene pyramiding is the ability to integrate multiple genes into a single plant, leading to increased production while maintaining nutritional quality. Biotic resistance, typically governed by a single gene, tends to be short-lived. Therefore, modern breeding approaches focus on pyramiding multiple genes or QTLs into a single genotype to ensure long-lasting resistance, contributing to sustainable agricultural production. Table 1 provides an overview of gene pyramiding in major crop species, highlighting its significance in enhancing disease resistance, insect resistance, and abiotic stress tolerance.

Table.1 An Overview of Gene Pyramiding in Significant Crop

Recurrent parent	Donor parent	Gene pyramided	Commercial variety
Pusa basmati -1	IRBB55	Xa13, Xa21 (BB Resistant)	Improved Pusa basmati -1
Samba Mahsuri	SS1113	Xa5, Xa13, Xa21 (BB Resistant)	Improved Samba Mahsuri
Swarna	IR 49830	SUB-1	Swarna Sub-1
Samba Mahsuri	IR 49830	SUB-1	Samba Mahsuri –Sub 1
Pusa Basmati -1	FL478	Saltol (salinity tolerance)	Improved Pusa Basmati -1

Conclusion

In a world where crop production and cultivation face various challenges, the application of molecular markers and MAS techniques in conventional plant breeding has ushered in a new era of innovation. Gene pyramiding, in particular, holds great promise for minimizing the

risks associated with reduced crop yields and quality due to biotic and abiotic stresses. The success of any breeding program is measured by its contribution to improving crop production. To achieve the goals of sustainable agriculture, breeders should fully utilize MAS gene pyramiding, ensuring the development of resilient and productive crop varieties. By harnessing the power of gene pyramiding, agriculture can address the evolving challenges it faces while ensuring global food security and agricultural sustainability.

Reference

1. Dormatey, Richard, Chao Sun, Kazim Ali, Jeffrey A. Coulter, Zhenzhen Bi, and Jiangping Bai. 2020. "Gene Pyramiding for Sustainable Crop Improvement against Biotic and Abiotic Stresses" *Agronomy* 10, no. 9: 1255. https://doi.org/10.3390/agronomy10091255